

(19)



Europäisches Patentamt

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(11)

EP 0 924 310 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

23.06.1999 Bulletin 1999/25

(51) Int. Cl.⁶: **C22C 21/02**

(21) Application number: **98123801.7**

(22) Date of filing: **15.12.1998**

(84) Designated Contracting States:

**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**

Designated Extension States:

AL LT LV MK RO SI

(30) Priority: **20.12.1997 GB 9726840**

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(54) **Aluminium alloy containing silicon for use as pistons in automobiles**

(57) An improved aluminium - silicon alloy for use in the manufacture of pistons is disclosed. The improved alloy is of the following composition in which the component elements are

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous
and either

- (i) 0.05 to 0.2 titanium; or
- (ii) at least one of the following

up to 0.2 zirconium
up to 0.2 vanadium;
in either case with the balance Aluminium and unavoidable impurities.

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Description

[0001] The present invention relates to a aluminium-silicon alloy. The alloy has use in the manufacture of pistons, in particular for pistons for use in internal combustion engines.

[0002] A satisfactory piston material must meet many differing requirements. In use, pistons are exposed to both static and dynamic stresses, while operating in bulk temperatures from sub-zero to up to 400°C. These stresses will also differ in different regions of the piston; for example a combustion bowl in a piston will be subject to different thermal and mechanical stresses than piston pin bosses. The piston must also have low thermal expansion, and possess good bearing characteristics with marginal lubrication over the noted range of temperatures. Also, the piston material must lend itself to being formed into a piston, for example by casting with subsequent working.

[0003] Known casting alloys for piston manufacture include those disclosed in Japanese Patent Application J01108339-A. Among the alloys disclosed therein is an aluminium based alloy including silicon from 9 to 12 percent, copper from 0.5 to 2.5 percent, magnesium from 0.8 to 2.0 percent, cobalt from 0.5 to 3 percent, nickel from 1 to 3 percent, iron from 0.3 to 1.0 percent, manganese from 0.1 to 1.0 percent and titanium from 0.01 to 0.15 percent with the balance being aluminium and unavoidable impurities. This alloy is said to provide high strength from 150 to 250 °C.

[0004] Another alloy is disclosed in DE 44 04 420 which may have application as an alloy for use in the manufacture of pistons for an automotive vehicle. The alloy comprises from 8.0 to 10.9 percent silicon, from 0.8 to 2.0 percent magnesium, from 4.0 to 5.9 percent copper, from 1.0 to 3.0 percent nickel, from 0.2 to 0.4 percent manganese, less than 0.5 percent iron and at least one element from the group including antimony, zirconium, titanium, strontium, cobalt, chrome and vanadium whereby at least one element is present in an amount greater than 0.8 percent and the sum of the elements in this group is no more than 0.8 percent, with the balance of the alloy being aluminium and unavoidable impurities.

[0005] The present invention has as an advantage that it provides good strength over the range of temperatures in which a piston made from the alloy operates.

[0006] The alloy of the present invention is selected from a group of aluminium alloys with each alloy component element being present in weight percent as follows:

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous
and either

- (i) 0.05 to 0.2 titanium; or
- (ii) at least one of the following

up to 0.2 zirconium
up to 0.2 vanadium;
in either case with the balance Aluminium and unavoidable impurities.

[0007] Preferably Zinc, Lead and Tin may also be present up to 0.15 weight percent. More preferably, the total amount of Lead and Tin may not exceed 0.15 weight percent.

[0008] The Copper allows age hardening of the alloy. An increase the amount of Copper beyond the limit stated reduces the high temperature fatigue strength of the alloy due to the generation of larger Copper-Nickel rich intermetallic crystals. An increase in the Copper level can also lead to shrinkage porosity problems in larger castings.

[0009] The Magnesium is present to contribute to the strength of the alloy. However, increasing the amount of Magnesium will lead to larger intermetallics in the as cast condition, but after aging these will be removed. The Magnesium is added at a level where it provides good strengthening after aging through the formation of Mg₂Si. Higher Magnesium levels lead to greater oxidation losses during the casting process, and thus a greater tendency for the cast metal to contain oxide defects.

[0010] The Nickel contributes to the high temperature strength of the alloy by the formation of thermally stable intermetallic crystals. However, exceeding the limits stated will reduce the high temperature fatigue strength of the alloy due to the precipitation of coarse intermetallic crystals. This tendency is made worse by the low cooling rates associated with the casting of large pistons.

[0011] The Cobalt content is chosen to allow the formation of a large number of small intermetallics. This is believed to improve the mechanical properties of the alloy at 350°C. In addition, the presence of the Cobalt in the Aluminium alloy at the levels stated is believed to reduce the diffusivity of the Copper in Aluminium, thereby slowing the overaging mechanism of the alloy.

This has particular importance when considering the operation of a piston pin boss operating at around 200°C. However, the presence of the Cobalt is believed also to lead to an increase in fatigue strength of the alloy at 350°C. This is of particular importance when considering the operation of a combustion bowl of a piston which is typically subject to such temperatures.

[0012] The Titanium or Zirconium and/or Vanadium are each present as a grain refining addition.

[0013] Preferably, the alloy may optionally include at least one of the following

up to 0.5 iron
up to 0.25 manganese

up to 0.05 chrome, and
up to 15 ppm each of calcium, sodium, strontium
and lithium.

[0014] The present invention will now be described, by
way of example only, with reference to the following
illustrative Examples. 5

Example 1

[0015] The use of a specific alloy composition in the
manufacture of forged pistons has proven to be particu-
larly advantageous. The metal alloy compositions of this
alloy with the component elements being indicated in
weight percent are as follows: 10

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
to 0.9 cobalt
0.05 to 0.2 titanium
at least 20 ppm phosphorous
with the balance Aluminium and unavoidable impu-
rities. 15

Example 2

[0016] Another alloy within the scope of the present
invention also found to have utility in the manufacture of
pistons has the following composition with the compo-
nent elements being indicated in weight percent as fol-
lows: 20

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous; and
at least one of the following
up to 0.2 zirconium
up to 0.2 vanadium;
with the balance Aluminum and unavoidable impu-
rities. 25

Example 3

[0017] Another alloy within the scope of the present
invention found to have utility in the manufacture of pis-
tons has the following composition with the component
elements being indicated in weight percent as follows: 30

10.5 to 11.5 silicon
2.5 to 3.5 copper
0.8 to 1.5 magnesium
0.5 to 1.5 nickel
0.3 to 0.7 cobalt 35

up to 0.20 titanium
up to 0.2 zirconium
up to 0.2 vanadium
up to 0.50 iron
up to 0.25 manganese
up to 0.05 chrome
up to 0.15 zinc
up to 0.15 lead
up to 0.15 tin; the total of lead and tin not to exceed
0.15
at least 20 ppm phosphorous
up to 15 ppm each of calcium, sodium, strontium
and lithium
with the balance Aluminium and unavoidable impu-
rities 40

[0018] The alloys of the present invention, in addition
to their use in the manufacture of forged pistons, may be
used in the manufacture of gravity die cast pistons. 45

Claims

1. An aluminium alloy in which the component ele-
ments are present in weight percent as follows: 50

10.5 to 13.5 silicon
2.0 to less than 4.0 copper
0.8 to 1.5 magnesium
0.5 to 2.0 nickel
0.3 to 0.9 cobalt
at least 20 ppm phosphorous
and either

- (i) 0.05 to 0.2 titanium; or
- (ii) at least one of the following

up to 0.2 zirconium
up to 0.2 vanadium;
in either case with the balance Aluminium and
unavoidable impurities. 55

2. An alloy according to claim 1, characterised in that
Zinc, Lead and Tin may also be present up to 0.15
wt% as unavoidable impurities.
3. An alloy according to claim 2, characterised in that
the total amount of Lead and Tin does not exceed
0.15 wt%.
4. An alloy according to any of claims 1 to 3, charac-
terised in that the alloy may optionally include at
least one of the following

up to 0.5 iron
up to 0.25 manganese
up to 0.05 chrome, and
up to 15 ppm each of calcium, sodium, stron-
tium and lithium. 60

5. A piston manufactured from an alloy according to any previous claim.

6. A piston according to claim 5, characterised in that the piston is manufactured by forging.

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7. A piston according to claim 5, characterised in that the piston is manufactured by gravity die casting.

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EUROPEAN SEARCH REPORT

Application Number
EP 98 12 3801

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 22 March 1999	Examiner Badcock, G
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons Δ : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03/92 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 98 12 3801

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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Information on patent family members

Int'l Application No

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 97/00088

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	<p>PATENT ABSTRACTS OF JAPAN vol. 014, no. 080 (C-0689), 15 February 1990 & JP 01 298131 A (KOBE STEEL LTD), 1 December 1989, see Table 2 of patent document see abstract</p> <p style="text-align: center;">---</p>	1-20
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